Semiconducting (Zn,Mg)O Structures

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- The objective of this work is to understand the synthesis and properties of carrier-doped (Zn,Mg)O structures

- For (Zn,Mg)O thin films, we have investigated the formation of acceptor states via phosphorus substitution on the oxygen site. Hole carrier dynamics is difficult to extract due to the low carrier density and carrier mobility. Using metal-insulator-semiconductor structures, we have extracted polarity type for phosphorus-doped structures. Figure 1 shows a capacitance-voltage measurement whose symmetry indicates p-type semiconducting behavior.

- In addition to the thin-film work, we have also examined the growth and transport properties of (Zn,Mg)O nanowire structures. Using a catalyst-driven molecular beam epitaxy approach, we have discovered the formation of self-assembled ZnO/(Zn,Mg)O cored heteroepitaxial nanowires. Depending on the conditions, we can assemble wires that are wurtzite ZnO, cubic (Mg,Zn)O, or ZnO/(Zn,Mg)O cored nanowires as seen in Figure 2.

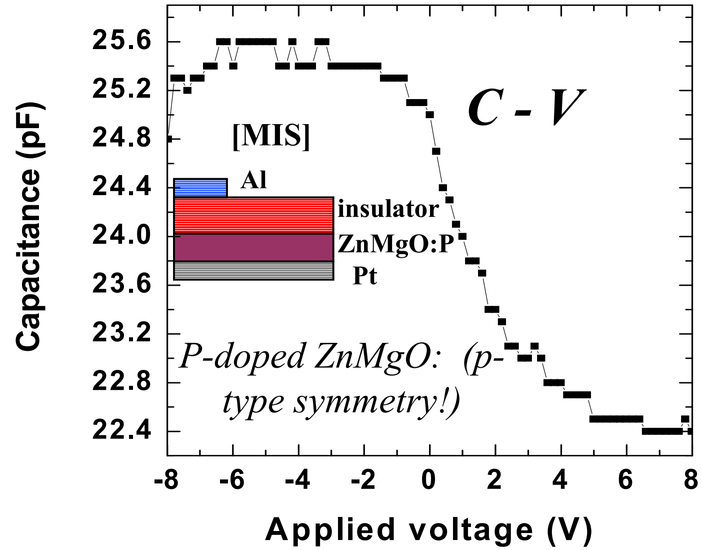

Fig. 1. Capacitance-voltage characteristics of P-doped (Zn,Mg)O MIS diode showing p-type behavior.

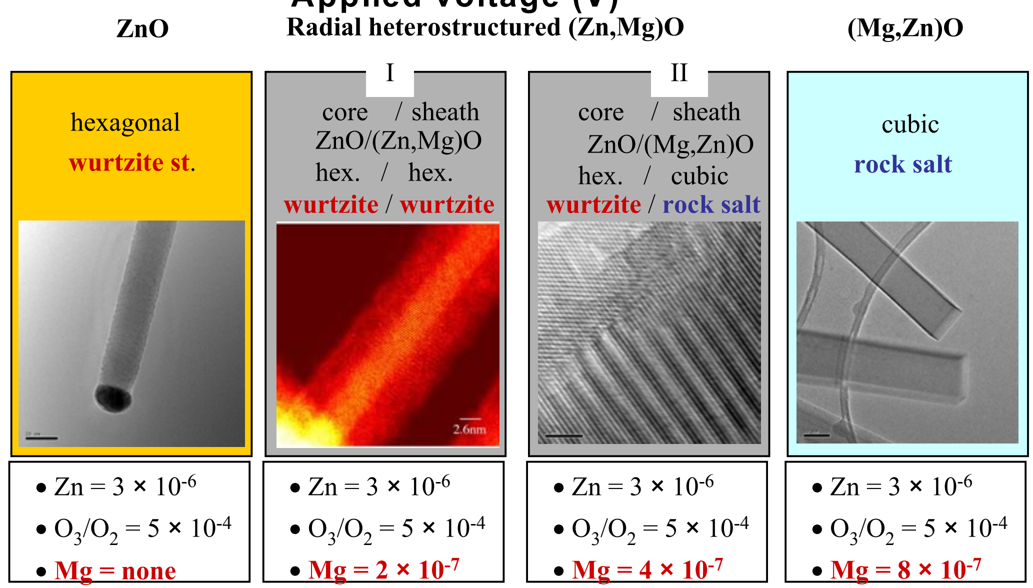

Fig. 2. TEM images of (Zn,Mg)O nanowires that can be selectively grown by catalyst-driven MBE

Aim of the project:

ZnO is an intriguing electronic material. It is a direct bandgap semiconductor whose gap energy can be tuned from 3.2 to 4 eV with substitution of Mg for higher bandgap. ZnO and related alloys are attractive for a number of applications, including high temperature electronics, transparent electronics, and blue to UV optoelectronics. The most significant impediment to the exploitation of (Zn,Mg)O in these applications is the difficulty in achieving effective carrier doping. In this project, the synthesis and properties of carrier-doped (Zn,Mg)O crystalline thin films and nanostructures are being investigated, with a focus on understanding the formation of acceptor and donor states.

Research results:

For (Zn,Mg)O thin films, the primary challenge has been the reproducible formation of acceptor-doped material. We have investigated the formation of acceptor states via phosphorus substitution on the oxygen site. Hole carrier dynamics is difficult to extract due to the low carrier density and carrier mobility. Using metal-insulator-semiconductor structures, we have extracted polarity type for phosphorus-doped structures. Figure 1 shows a capacitance-voltage measurement whose symmetry indicates p-type semiconducting behavior.

In addition to the thin-film work, we have also examined the growth and transport properties of (Zn,Mg)O nanowire structures. Such structures are interesting in understanding the fundamental properties of low-dimensional semiconductors and have significant potential in sensor applications. Using a catalyst-driven molecular beam epitaxy approach, we have discovered the formation of self-assembled ZnO/(Zn,Mg)O cored heteroepitaxial nanowires. Depending on the conditions, we can assemble wires that are wurtzite ZnO, cubic (Mg,Zn)O, or ZnO/(Zn,Mg)O cored nanowires as seen in Figure 2.

Significance of this work:

Understanding the doping behavior of group V impurities in ZnO-related materials is key to developing UV photonics and transparent electronics. In addition, the topic of bipolar doping is relevant to a number of wide bandgap oxide materials. The nanowire activities provide a unique means of forming cored heteroepitaxial structures for low-dimensional transport studies

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Education:

This work involves the collaboration of three graduate students (Jean-Marie Erie, Yuanjie Li, and Li-Chia Tien), two undergraduate (Anwar Cumberbatch and Fernando Lugo), and a post-doctoral scientist (YoungWoo Heo).

The Norton group has monthly presentations by students that include topical reviews. The undergraduates are fully integrated into the group, having independent research projects in thin films and nanomaterials

Outreach:

Within the group, we are developing a tutorial presentation focusing on oxide electronic oxide thin-film material synthesis, properties and applications. The tutorial will be relevant to many issues with oxide electronic material science including nanomaterial synthesis, prospective device applications. The tutorial will be placed on the web